IN THE UNITED STATES PATENT & TRADEMARK OFFICE

Inventor:	Paul S. Prevey, III	)
		)
Serial No.:	09/516,327	) Examiner: Edward Lefkowitz
		)
Filed:	March 1, 2000	)
		)
Title:	"Method for Reducing Tensile Stress Zones in the Surface of a Part"	)
		)
Date:	December 7, 2011	)
		)
Atty. Docket:	LMBD-110520.004	)

REQUEST FOR ISSUANCE OF CERTIFICATE OF CORRECTION

FILED BY EFS-Web

Honorable Commissioner of Patents and Trademarks
Mail Stop: Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

Patentee, for the reasons set forth in the remarks and exhibits that follow, requests the issuance of a Certificate of Correction for U.S. Pat. No. 6,622,570; to correct an error made by the U.S.P.T.O during Ex Parte Reexamination of this patent.

Remarks begin on page 2 of this paper.

Nine sequentially numbered Exhibits begin on page 4 of this paper.

REMARKS

Applicant believes that the U.S.P.T.O. erroneously entered an improper set of allowed claims into Ex Parte Reexamination Certificate (6442nd) for U.S. Pat. No. 6,662,570 C1, said Reexamination Certificate being issued September 16, 2008.

1. Ex Parte Reexamination of U.S. Pat. No. 6,662,570 C1 (Exhibit 1) was granted on March 30, 2005; and was assigned application number 90/007,383.

2. Near the completion of the Reexamination, Applicant entered a set of amended claims on July 13, 2006 (Exhibit 2), which were rejected in part (Claims 1, 2, and 4-8) and found patentable or confirmed in part (Claims 3, 9-11) on August 11, 2006.

3. Applicant and Examiners held an Ex Parte Interview on September 7, 2006, during which the application and possible further amendment was discussed.

4. Applicant filed an Interview Summary under 37 C.F.R. 1.560(b) on September 8, 2006. (Exhibit 3)

5. The Examiners filed an Ex Parte Reexamination Interview Summary on September 22, 2006 (Exhibit 4).

6. Applicant concurrently filed a Response and Amendment on September 8, 2006, making arguments and amendments as had been discussed in the Interview. (Exhibit 5)

7. Handwritten notations, "PLEASE ENTER – 9/26/06" and "ok to enter (signature) Mark J. Reinhart, SPRE-AU 3992 Central Reexamination Unit" were entered in the file history in regards to the amendments of September 8, 2006. (Exhibit 6)

8. A Statement of Reasons for Patentability and/or Confirmation was entered into the record on October 3, 2006; by Examiners Minh Nguyen and Mark J. Reinhart. (Exhibit 7)

9. Ex Parte Reexamination Certificate (6442nd) for U.S. Pat. No. 6,662,570 C1, was issued September 16, 2008. (Exhibit 8)

10. However, for reasons unknown, the Reexamination Certificate was printed with the July 13, 2006 set of amended claims (Exhibit 1), rejected as of August 11, 2006; instead of the set of allowed claims filed September 8, 2006 (Exhibit 4); and entered by the Examiners on September 26, 2006. (Exhibits 5, 6)

11. Applicant hereby requests correction to reflect that the Reexamination Certificate should have been issued with the September 8, 2006 claims, as entered, and provides a clean copy of those claims herein as Exhibit 9.

Respectfully submitted,

December 7, 2011

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EXHIBIT 1

US006622570B1

(12) **United States Patent**
Prevey, III

(10) **Patent No.: US 6,622,570 B1**
(45) **Date of Patent: Sep. 23, 2003**

(54) **METHOD FOR REDUCING TENSILE STRESS ZONES IN THE SURFACE OF A PART**

(75) Inventor: **Paul S. Prevey, III**, Cincinnati, OH (US)

(73) Assignee: **Surface Technology Holdings Ltd.**, Cincinnati, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/516,327**

(22) Filed: **Mar. 1, 2000**

(51) **Int. Cl.**⁷ **G01N 3/08**
(52) **U.S. Cl.** **73/826; 72/75**
(58) **Field of Search** 73/11.02, 862.043, 73/826; 72/75, 379.6, 379.2; 29/90.01

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Statistical Analysis of the Effects of Ball Burnishing Parameters on Surface Haroness, by. N.H. Loh, S.C. Tam, B. Miyazawa, Elsevier Sequola (1988).

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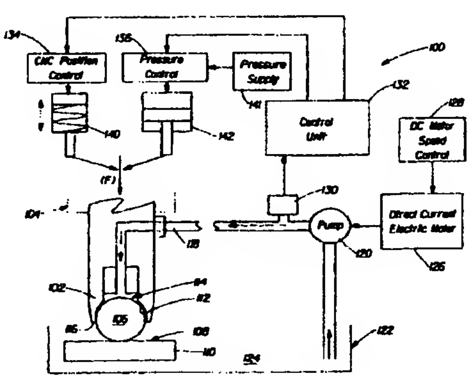
Primary Examiner—Edward Lefkowitz
Assistant Examiner—Lilybett Martir
(74) *Attorney, Agent, or Firm*—Mark F. Smith; Smith Brandenburg Ltd.

(57) **ABSTRACT**

The present invention is a novel method for reducing tensile zones in the surface of a part comprising the steps of selecting a region of the part to be treated and programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing and the magnitude of compression are varied to reduce the high tensile stress along the boundaries of the selected region. In a preferred embodiment of the invention the burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

11 Claims, 9 Drawing Sheets



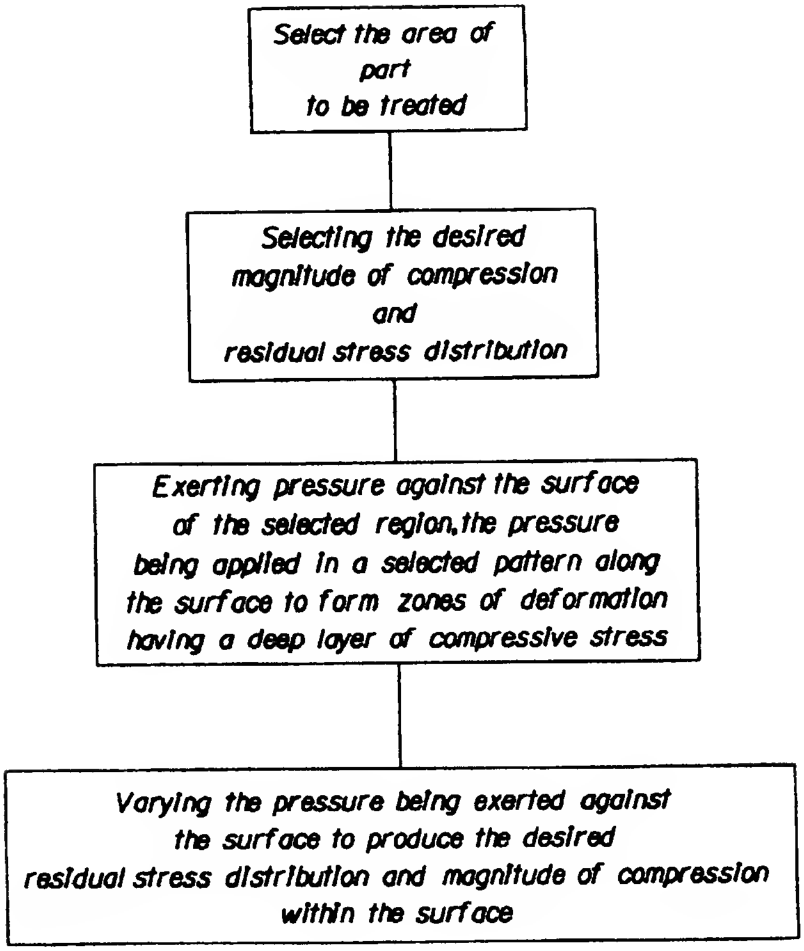

Select the area of part to be treated
Selecting the desired magnitude of compression and residual stress distribution
Exerting pressure against the surface of the selected region,the pressure being applied in a selected pattern along the surface to form zones of deformation having a deep layer of compressive stress
Varying the pressure being exerted against the surface to produce the desired residual stress distribution and magnitude of compression within the surface

Fig. 1

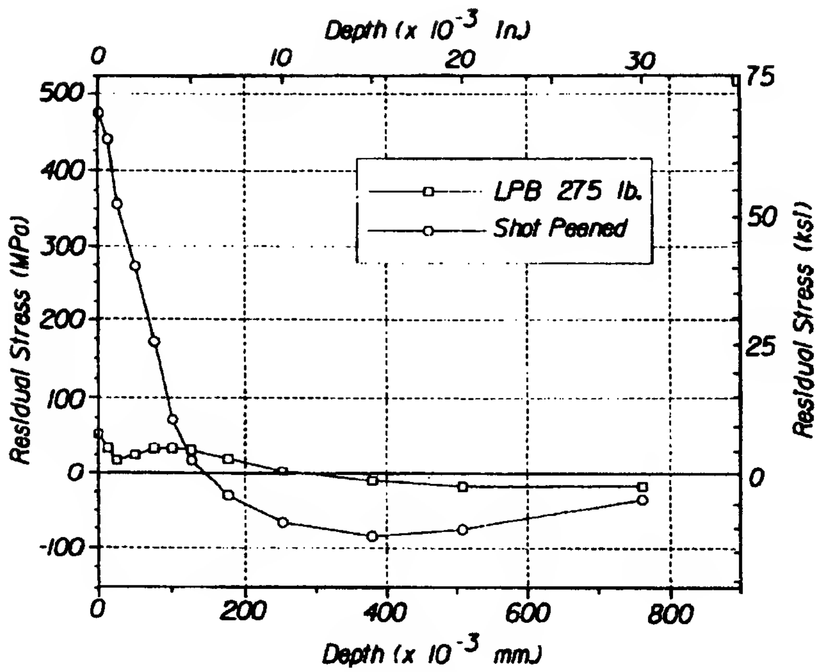

Depth (x 10⁻³ in.)
0
10
20
30
500
400
300
200
100
0
-100
75
50
25
0
Residual Stress (MPa)
Residual Stress (ksi)
LPB 275 lb.
Shot Peened
0
200
400
600
800
Depth (x 10⁻³ mm)

Fig. 2

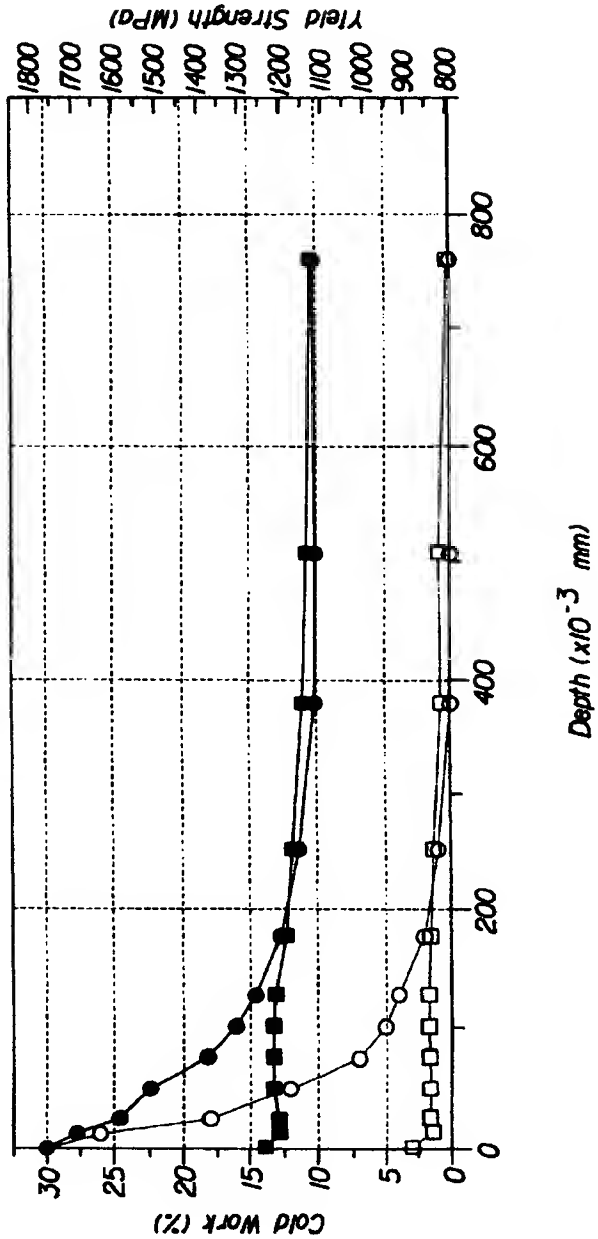

Yield Strength (MPa)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
Cold Work (%)
30
25
20
15
10
5
0
Depth (x10^-3 mm)
0
200
400
600
800

Fig. 3

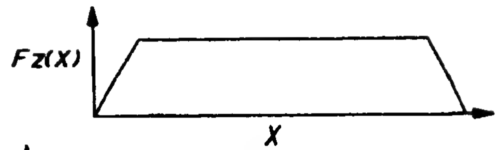
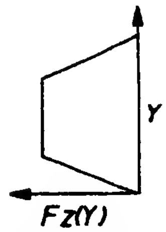


Fig. 4A



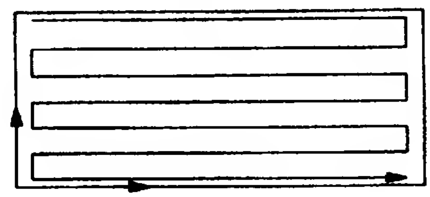


Fig. 4C

Fig. 4B

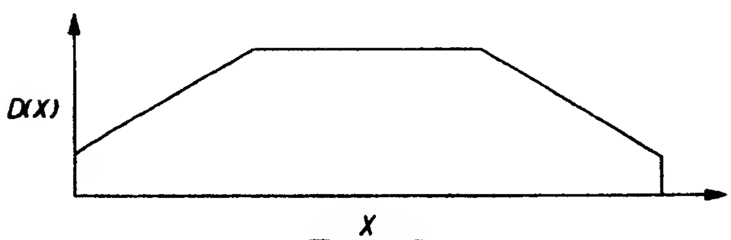


Fig. 5A

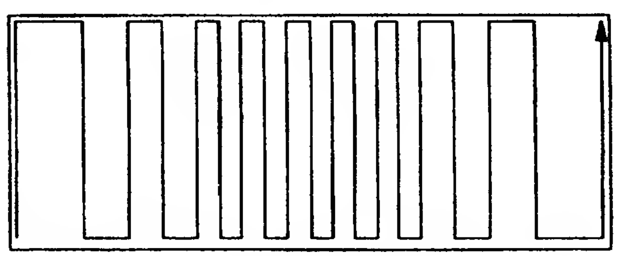


Fig. 5B

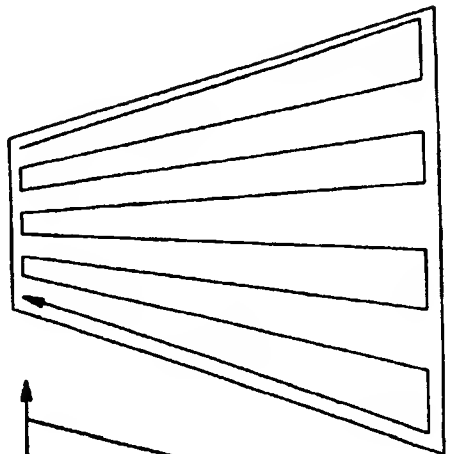


Fig. 6B

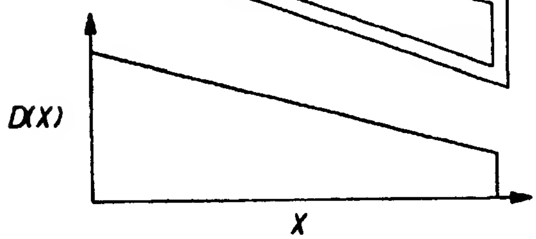


Fig. 6A

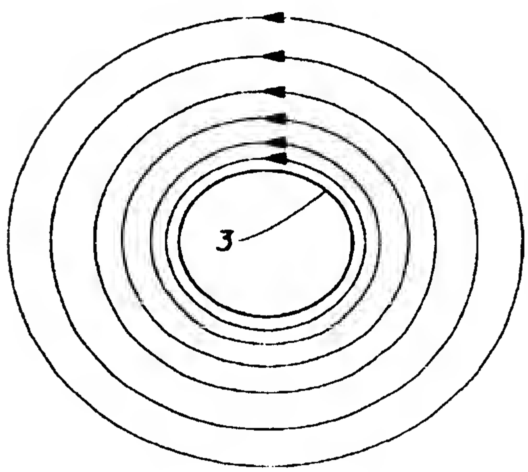


Fig. 7

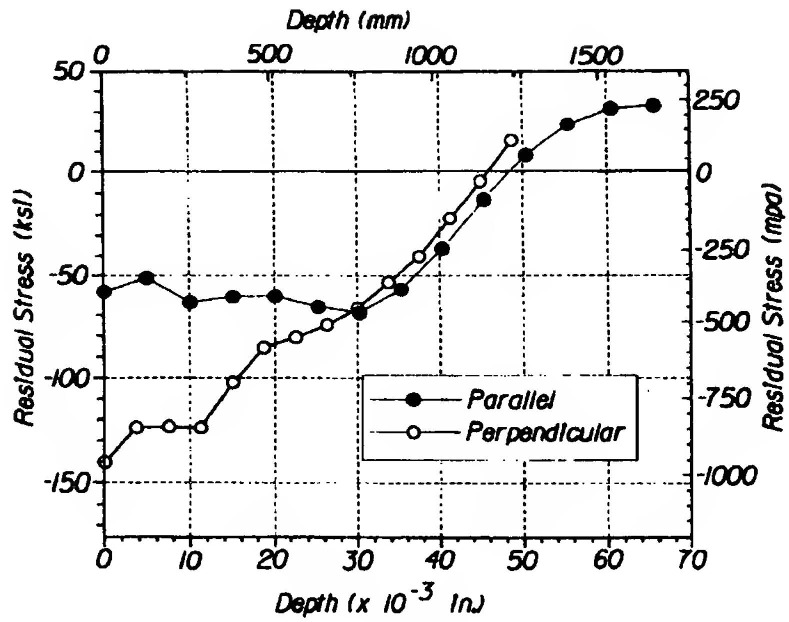

Depth (mm)
0
500
1000
1500
50
0
-50
-100
-150
250
0
-250
-500
-750
-1000
Residual Stress (ksi)
Residual Stress (mpa)
Parallel
Perpendicular
0
10
20
30
40
50
60
70
Depth (x 10-3 in.)

Fig. 8

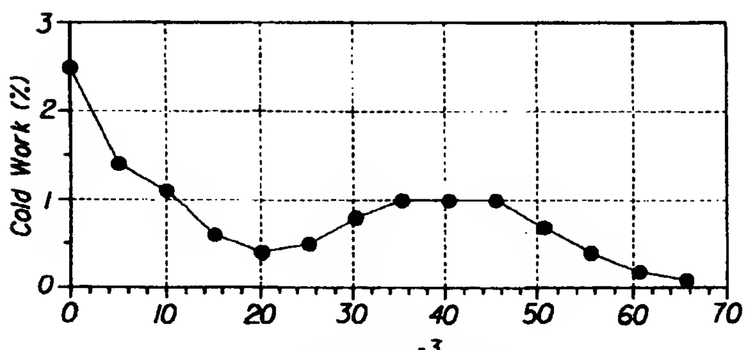

3
2
1
0
Cold Work (%)
0
10
20
30
40
50
60
70
Depth (x10-3 in.)
4340 Steel LPB Coupon

Fig. 9

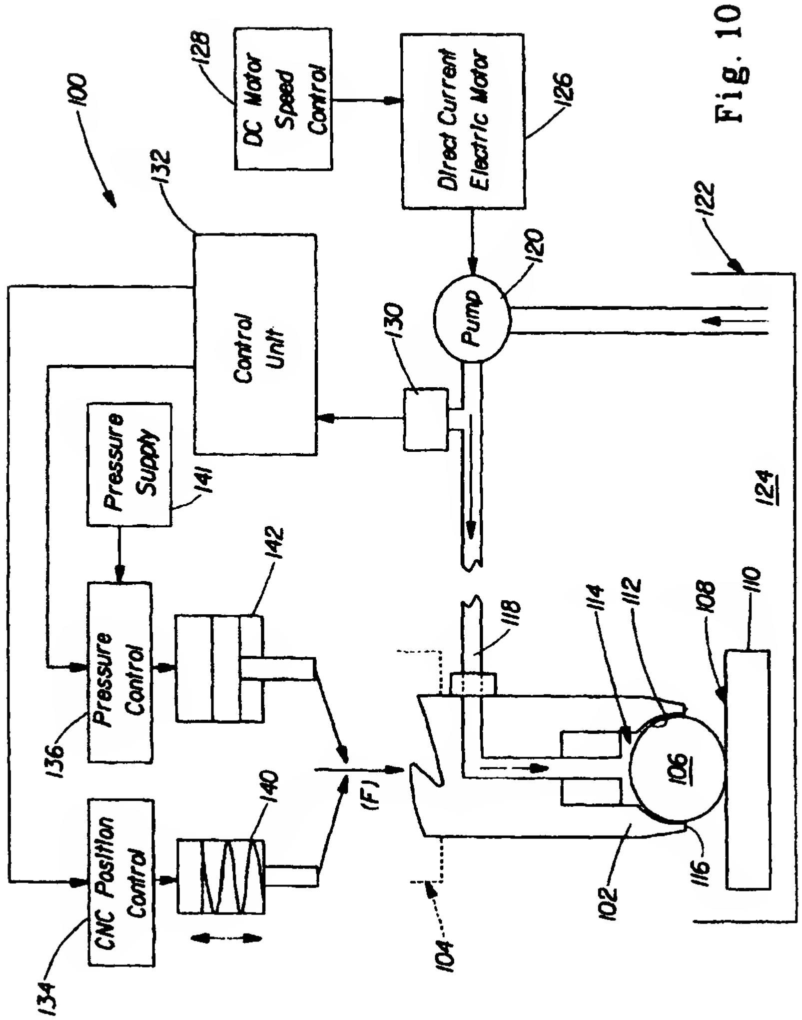

100
DC Motor Speed Control
128
Direct Current Electric Motor
126
132
Control Unit
Pump
120
122
130
Pressure Supply
141
124
Pressure Control
136
142
118
114
112
108
110
CNC Position Control
134
140
(F)
106
102
116
104

Fig. 10

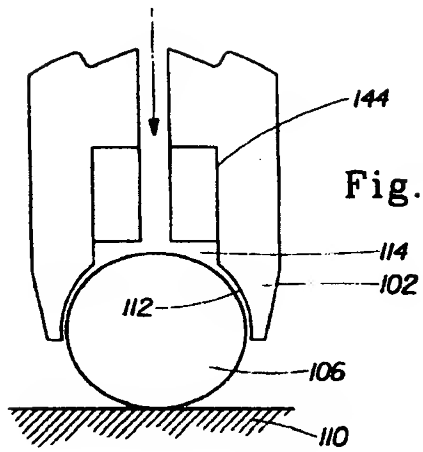


Fig. 11

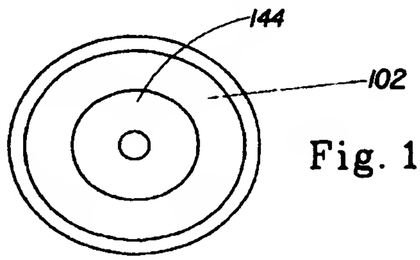


Fig. 12

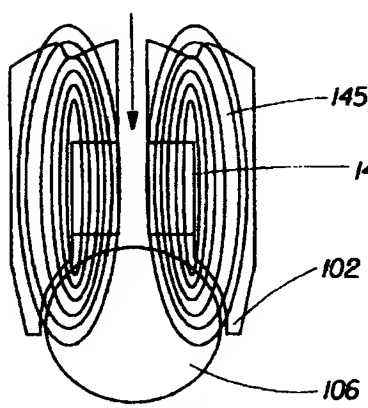


Fig. 13

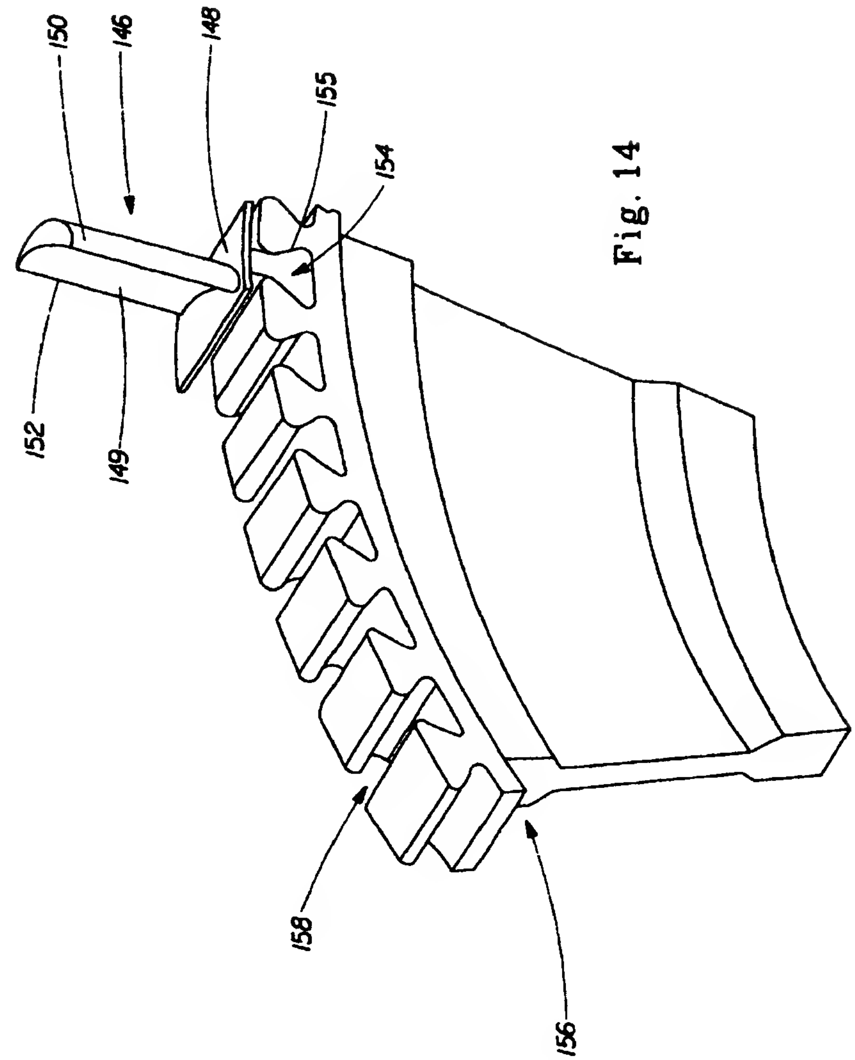


Fig. 14

METHOD FOR REDUCING TENSILE STRESS ZONES IN THE SURFACE OF A PART

RELATED PATENT APPLICATIONS

The present Application deals with related subject matter in co-pending U.S. patent application entitled METHOD AND APPARATUS FOR PROVIDING A RESIDUAL STRESS DISTRIBUTION IN THE SURFACE OF A PART, filed on the same day as the present application and having the same inventor in common.

BACKGROUND OF THE INVENTION

This invention relates to a method for reducing tensile stress zones in the surface of a part and, more particularly, to a method of reducing or eliminating tensile stress zones or concentrations within the surface of a part to improve fatigue and stress corrosion performance of the part and an apparatus for implementing the method.

Surface residual stresses are known to have a major effect upon the fatigue and stress corrosion performance of component parts. Tensile residual stresses, which can develop during manufacturing processes such as grinding, turning, or welding are well known to reduce both fatigue life and increase sensitivity to corrosion-fatigue and stress corrosion cracking of the part. Further, many parts that are subjected to high dynamic stresses or have areas where stress concentrations occur, such as blades and the rotor disks of turbo machinery, are prone to crack initiation and relatively rapid crack growth. The blades typically comprise an airfoil portion, a platform for partially defining a surface for fluid flow there over when the blade is mounted to the rotor disk, and a root portion having retention grooves which engage in corresponding axially extending complementary grooves of the disk. During engine operation, the rotor disk and the blade are subjected to large centrifugal loads that produce high dynamic stresses that may cause high cycle fatigue along portions of the rotor disk and the blade causing cracking and possible failure of the part. Further, the leading edge of the airfoil is often subjected to damage caused by the impact of foreign objects in the fluid stream. Such impact often results in cracks forming along the leading edge that may result in failure of the blade.

It is well known that compressive residual stresses induced in the surface of a part can increase fatigue life and reduce susceptibility to corrosion-fatigue and stress corrosion cracking. There are currently several methods used in industry for inducing compressive stress in the surface of a metal part and the particular method selected has been dependent on factors such as the dimensions and shape of the part, its strength and stiffness, the desired quality of the finished surface, the desired physical properties of the finished part, and the expense of performing the operation.

One method commonly used in industry to induce compressive stress in the surface of a part is shot peening, whereby a plurality of metallic or ceramic pellets are projected mechanically or through air pressure to impinge the surface of the part. While such a method is relatively inexpensive and is preferred for many applications, shot peening is unacceptable for parts requiring a superior finish or requiring a greater depth of compressive stress penetration and has also been found to be unacceptable for parts requiring localized or well defined compressive stress regions. Further, for parts such as a rotor disk for use in turbo machinery, the bore surfaces of the rotor disk are subjected

to low levels of plastic strain (typically between about 0.2% to about 0.5%) when the rotor disk is accelerated to full speed. If the surfaces have been highly cold worked, such as during shot peening, the cold worked compressive surface material will not yield in tension while the lower yield strength interior material will yield during engine operation. On unloading, such as when the rotor speed is reduced, the surface is driven into tension and will remain in tension, reducing its fatigue life, for the remaining life of the component.

Another method commonly used in industry to induce compressive stress in the surface of a part is laser shock peening, whereby multiple radiation pulses from high power pulsed lasers produce shock waves on the surface of the part to produce a high magnitude localized compressive stress within a particular region. Unfortunately, however, laser shock peening is relatively expensive and time consuming making it unacceptable for many applications.

A method which have been developed and is widely used in industry to improve surface finish, fatigue life, and corrosion resistance by deforming the surface of a part is burnishing whereby a rotary or sliding burnishing member is pressed against the surface of the part in order to compress the microscopic peaks in the surface into adjacent hollows. Burnishing operates to develop compressive stresses within the part by yielding the surface in tension so that it returns to a state of compression following deformation.

The burnishing apparatus utilized for working the surface of a part typically comprise a plurality of cylindrical rollers or balls which contact the surface of the part with sufficient pressure to induce a compressive stress therein. The introduction of a region of high compressive residual stress will necessarily require tensile stresses elsewhere in the part to achieve equilibrium. Equilibrium only requires that the sum of all the normal stresses and moments acting on any plane through the entire part sum be zero. Unfortunately, sharp surface demarcation typically exists along the boundaries of the burnished area. It has been found that depending upon the geometry and stress filed, tensile residual stresses are often formed along such boundaries. As disclosed herein, it has been found that gradually reducing the pressure being exerted by the burnishing member to reduce the magnitude of compression at the boundaries will reduce the build up of tensile residual stress. Further, it has been found that by controlling the compressive residual stress distribution and the magnitude of compression, the tensile stress distributions within a part may be offset or distributed in such a manner as to optimize the fatigue and/or stress corrosion performance of the part. Until now, however, a method and apparatus have not been developed that permitted the residual stress distributions and the magnitude of compression to be controlled in such a manner as to optimize fatigue performance for a specific applied stress distribution.

Consequently, a need exists for a relatively inexpensive, relatively time efficient method and apparatus for implementing the method for improving the physical properties of a part by inducing a layer of compressive stress in the surface of the part, which is effective for use with complex shaped surfaces, and which permits the magnitude of compression and the residual stress distributions to be produced on a surface to achieve optimum fatigue performance and stress corrosion performance of the part.

SUMMARY OF THE INVENTION

The novel method of the present invention for reducing or eliminating tensile stress zones or concentrations immedi-

ately adjacent and parallel to the boundaries of compressive zones produced by a surface enhancement operation comprising the steps of selecting a region of the part to be treated and performing an operation of inducing a layer of compressive stress within the surface such that the magnitude of compression is reduced in the direction towards the boundaries of the compressive zones.

In another preferred embodiment of the invention, the step of exerting pressure against the surface of the selected region included performing a burnishing operation using a burnishing apparatus having a burnishing member for exerting pressure against the surface of the selected region of the part to produce a zone of deformation having a deep layer of compression.

In another preferred embodiment of the invention, the pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 5.0%.

In another preferred embodiment of the invention, the pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 3.5%.

In another preferred embodiment of the invention, whereby the step of exerting pressure on the surface of the part is performed by a burnishing operation using a burnishing apparatus having a burnishing member for exerting pressure against the surface of the selected region to induce a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

In another preferred embodiment of the invention, whereby the step of exerting pressure on the surface of the part is performed by a burnishing operation using a burnishing apparatus having a burnishing member for exerting pressure against the surface of the selected region to induce a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

In another preferred embodiment of the invention, whereby the selected pattern operates to vary the spacing between the zones of deformation to produce the desired residual stress distribution.

In another preferred embodiment of the invention, the step of selecting the magnitude of compression includes the step of programming a control unit to automatically adjust the pressure being exerted against the surface of the part.

In another preferred embodiment of the invention, the step of exerting pressure against the surface of the selected region includes performing a burnishing operation and the step of programming a control unit to control the direction of movement of a burnishing member to produce the desired stress distribution.

In another preferred embodiment of the present invention the step of varying the pressure being exerted against the surface of a part includes the steps of programming a control unit to adjust the pressure being exerted by a burnishing member against the surface of the part, and programming the control unit to direct the burnishing member over the part in a selected pattern to obtain the desired residual stress distribution.

In another preferred embodiment of the present invention, the step of varying the pressure being exerted against the surface of a part includes the step of gradually varying the magnitude of compressive stress in the areas immediately adjacent to the boundaries of the selected region.

The novel apparatus for implementing the method of the present invention utilizes a burnishing process for inducing a layer of compressive residual stress having a preselected magnitude of compression and a desired stress distribution. In particular, the burnishing apparatus comprises a burnishing member for applying pressure against the surface of the selected region of the part to produce a zone of deformation having a deep layer of compression and a preselected magnitude within the surface. The burnishing apparatus further comprises means for moving the burnishing member in a predetermined pattern across the selected region to produce a desired residual stress distribution.

In another preferred embodiment of the invention the burnishing apparatus for implementing the burnishing method of the subject invention comprises a burnishing member for applying pressure against the surface of a part to induce a layer of compressive stress therein; means for adjusting the pressure being applied against the surface of the part by the burnishing member; and means for directing the burnishing member over the surface of the part in a predetermined pattern to provide the desired residual stress distribution.

In another preferred embodiment of the invention, the burnishing apparatus for implementing the burnishing method of the subject invention is coupled to a control unit for automatically controlling the movement, position, and application pressure of the burnishing member.

In another preferred embodiment of the invention, the burnishing apparatus for implementing the burnishing method of the subject invention comprises means for supplying a constant flow of fluid to support the burnishing member.

In another preferred embodiment of the invention, the burnishing apparatus for implementing the burnishing method of the subject invention comprises magnetic means for maintaining the burnishing member within the socket.

Another preferred embodiment of the invention is a blade for use in turbo machinery having a desired stress distribution.

Another preferred embodiment of the invention, a part selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, pump parts, and the like comprises regions of compressive residual stresses having predetermined stress distributions.

Another preferred embodiment of the invention, a part selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, pump parts, and the like treated by the method comprising the step, or a combination of steps, of the present invention.

A primary object of this invention, therefore, is to provide a method and an apparatus for implementing the method of providing a part with an improved finish and with improved physical properties.

Another primary object of this invention is to provide a method and an apparatus for implementing the method of inducing a compressive stress layer on the surface of a part.

Another primary object of this invention is to provide a method and an apparatus for implementing the method of inducing a compressive stress layer that varies in magnitude of compression across the part in a predetermined pattern.

Another primary object of this invention is to provide a method and an apparatus for implementing the method of inducing a compressive stress layer having a well defined stress distribution.

Another primary object of this invention is to provide a method and an apparatus for implementing the method of

inducing a compressive stress layer having a predetermined stress distribution.

Another primary object of this invention is to provide a method for forming a part having deep compression with a minimal amount of cold working and surface hardening.

Another primary object of the invention is to provide a burnishing apparatus that permits the pressure being exerted on the surface of a part to be varied to produce regions having residual stress distributions of arbitrary shape and magnitude of compression.

Another primary object of this invention is to provide an apparatus having a burnishing member within a socket which can be easily removed and inserted into place within the socket.

Another primary object of this invention is to provide a method and an apparatus for implementing the method of inducing a compressive stress layer on the surface of a part which is relatively inexpensive.

Another primary object of this invention is to provide a blade for use in turbo machinery comprising regions of compressive residual stresses having predetermined stress distributions.

Another primary object of this invention is to provide a blade for use in turbo machinery having a compressive stress layer that varies in magnitude of compression across the part.

Another primary object of this invention is to provide a disk for use in turbo machinery comprising regions of compressive residual stresses having predetermined patterns of magnitude of compression and residual stress distribution.

Another primary object of this invention is to provide a part selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, pump parts, and the like comprising regions of compressive residual stresses having predetermined patterns of magnitude of compression and residual stress distributions.

These and other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram illustrating the method of the present invention;

FIG. 2 is a graph illustrating the predicted longitudinal residual stress distribution, following 2.1% plastic strain, of a part having been treated by the method of shot peening and a part having been treated by the method of burnishing;

FIG. 3 is a graph illustrating the percent of cold work and yield strength distribution of a part having been treated by the method of shot peening and a part having been treated by the method of burnishing;

FIG. 4 is a schematic view of a generally rectangular region being treated by the method and apparatus of the invention for inducing a desired residual stress distribution and magnitude of compression whereby the pressure being exerted (force normal to the surface) against the surface is varied in two directions;

FIG. 5 is a schematic view of another region being treated by the method and apparatus of the invention for inducing a desired residual stress distribution and magnitude of compression whereby the density of the burnishing pattern is varied in the one direction;

FIG. 6 is a schematic view of another region being treated by the method and apparatus of the invention for inducing a desired residual stress distribution and magnitude of compression whereby the density of the burnishing pattern is varied in the two directions;

FIG. 7 is a schematic view of another region being treated by the method and apparatus of the invention for inducing a desired residual stress distribution and magnitude of compression, such as around a bolt hole, whereby the pattern is a symmetrical pattern;

FIG. 8 is a graph illustrating the residual stress distribution induced in the surface of a part in the direction of burnishing (parallel) and in the transverse direction (perpendicular);

FIG. 9 is a graph illustrating the percent cold work distribution for the burnishing operation shown in FIG. 8;

FIG. 10 is a diagrammatic view of the burnishing apparatus for implementing the method of the present invention;

FIG. 11 is a diagrammatic view of the socket of a preferred embodiment of the burnishing apparatus of the present invention showing magnetic means for maintaining the burnishing member within the socket;

FIG. 12 is a bottom diagrammatic view of the socket of FIG. 11 with the burnishing member removed;

FIG. 13 is a diagrammatic view of the socket of FIG. 11 showing the magnetic field lines for maintaining the burnishing member within the socket; and

FIG. 14 is a partial perspective view of a blade and a rotor disk of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a method and an apparatus for implementing the method of inducing a layer of compressive residual stress along the surface of a part. In a preferred embodiment of the invention, as shown in FIG. 1, the method of the present invention comprises the steps of selecting a region of the part to be treated; selecting the magnitude of compression and the residual stress distribution to be induced along the surface of the selected region, such as for example by finite element analysis; and inducing a layer of compressive residual stress along the surface of the selected region having the desired magnitude of compression and stress distribution.

It has been found that for parts having a surface that has been substantially cold worked, such as a rotor disk for turbo machinery that has been treated by the process of shot peening, the cold worked compressive surface material will typically not yield in tension, such as during high speed operation, while the lower yield strength interior material will yield. On unloading of the part, such as when the speed of revolution of the rotor disk slows, the surface of the part is driven into tension and will remain in tension, reducing the fatigue life, throughout the parts remaining life. Referring to FIG. 2, the inversion into tension of a surface of a part having been treated by the method of shot peening is shown compared to a surface of a part having been treated by the method of burnishing, each having a 2.1% plastic strain single cycle. Referring to FIG. 3, the corresponding percent of cold work and yield strength distribution are shown. As illustrated, upon unloading, the part that underwent the method of shot peening may actually invert from compression into a relative high level of tension, if a yield strength gradient exists, thereby significantly reducing the fatigue life of the part.

Accordingly, it has been found that the preferred method of the present invention for improving the surface finish, fatigue life, and stress corrosion resistance of a part is burnishing, whereby a rotary or sliding member is pressed against the surface of the part in order to compress the microscopic peaks in the surface into adjacent hollows. Such compression develops compressive stresses within the part by yielding the surface in tension so that it returns to a state of compression following deformation. As shown in U.S. Pat. No. 5,826,435, by the same inventor and incorporated herein by reference, by cold working the surface less than about 3.5%,and preferably less than about 2.0%, results in layer retention of compressive residual stress at elevated temperature, less rapid relaxation under cyclic loading, and minimizes the alteration of the residual stress field during tensile or compressive overload than conventional cold working and surface hardening processes. Accordingly, the method of the present invention is shown in FIG. 1 and preferably utilizes the process of burnishing to provide deep compression with a minimal amount of cold working and surface hardening. In particular, the region to be burnished along the surface of the part is first defined and a burnishing apparatus having a single-point of contact burnishing member is pressed against the surface of the part to create a zone of deformation producing a relatively deep layer of compression within the surface. The burnishing member is then passed in a predetermined pattern across the region. Preferably, the pattern of burnishing is such that the zones of deformation formed by each pass of the burnishing member do not overlap. As disclosed in U.S. Pat. No. 5,826,435, applying a single-pass, or multiple passes having a reduced compressive pressure, produces compressive residual stresses following tensile deformation of the surface having deep compression with minimal cold working.

In another preferred embodiment of the invention, the method further comprises the steps of determining the optimum magnitude of compression to be induced at particular points along the surface of the selected region by controlling the pressure being exerted by the burnishing member. In another preferred embodiment of the invention, the method comprises the steps of varying the pattern of burnishing to produce a desired residual stress distribution. In another preferred embodiment of the invention, the method further comprises the steps of programming a control unit, such as a computer or numerical controller, to automatically regulate the burnishing force being applied to the burnishing member thereby controlling the pressure being exerted against the surface of the part and the corresponding magnitude of compression being induced by the burnishing apparatus. The control unit may also be programmed to control the direction of movement of the burnishing apparatus to produce the desired residual stress distribution.

The particular pressure and the pattern of burnishing for a part may be selected whereby the magnitude of compression and the residual stress distribution optimizes the fatigue performance of the part. For illustration, as shown in FIG. 4, a rectangular burnishing region is selected and the burnishing member is pressed against the surface of the part in a particular (raster) pattern, as shown by the arrow indicating the path of the burnishing member. The normal force (Fz) being applied to the burnishing member is varied to increase or decrease the pressure being exerted against the surface of the part. While FIG. 4 shows a linear variation in the normal force and the corresponding pressure being applied against the surface, parallel (X-direction) and perpendicular (Y-direction) to the direction of burnishing, it should now be apparent to those skilled in the art that the pattern of burnishing and the form and rate of reduction or increase in pressure being exerted against the surface can be controlled to provide a wide variety of residual stress distributions and magnitude of compression.

Referring to FIG. 5, another illustration of the method of the present invention is shown whereby variations in residual stress distribution may also be achieved by varying the pattern of burnishing, independently or in conjunction with variations in burnishing pressure. As shown, the spacing along the X-direction, perpendicular to the direction of travel of the burnishing member, has been varied to increase and decrease the spacing between each pass of the burnishing member thereby changing the the density (Dx) of burnishing (spacing density). As shown, the spacing between each pass of the burnishing member varies linearly, however, it should now be apparent to those skilled in the art that other burnishing patterns may be selected to produce the desired residual stress distribution.

Referring to FIG. 6, another pattern of burnishing is shown whereby the density of burnishing (Dx) is varied in two dimensions (X and Y directions) as a function of the length of the burnishing pass, in order to produce the desired stress distribution for the part being burnished.

Referring to FIG. 7, another pattern of burnishing is shown whereby a region is designated and the magnitude of compression and the residual stress distribution is selected that optimizes the fatigue performance of the part. As shown, the residual stress distribution has a symmetrical pattern such as what would be preferred for use around bolt holes or for "feathering" in a state of compressive stress in the fillet area of a rotor disk. It should now be apparent to those skilled in the art that the burnishing pressure, the density of burnishing, and the pattern of burnishing can be varied to produce the desired residual stress distribution and magnitude of compression for a part for a specific engineering application.

In addition, it is know that introducing a region of high compressive residual stress requires tensile stresses to exist elsewhere in the part to achieve equilibrium. Unfortunately, sharp surface demarcation or discontinuities typically exists along the boundaries of the burnished area and, depending upon the geometry and stress filed, tensile residual stress zones or concentrations often form along such boundaries. Such stress zones can significantly reduce the fatigue life of the part. It has been found that gradually reducing the pressure being exerted by the burnishing member to reduce the magnitude of compression in the direction towards the boundaries ("feathering") will reduce the build up of such tensile residual stress. Further, it has been found that by controlling the compressive residual stress distribution and the magnitude of compression, the tensile stress distributions within a part may be offset or distributed in such a manner as to optimize the fatigue and/or stress corrosion performance of the part.

The method for inducing a layer of compressive residual stress along the surface of a part and the apparatus for implementing the method provides control of the particular stress distribution and magnitude of compression that optimizes the fatigue performance of the part. By controlling the pattern of burnishing, such as the density of burnishing, and by gradually reducing the magnitude of compression near the boundaries of the regions being burnished ("feathering"), the tensile stress zones which occur immediately adjacent and parallel to the boundaries of the regions being treated may be reduced or eliminated.

In another preferred embodiment of the invention, the method of inducing a layer of compressive residual stress along the surface of a part includes the step of using a secondary process, such as shot peening, grit blasting, tumbling or other similar abrasive impact processes to induce a shallow layer of compressive residual stress near the surface of the part following burnishing. As shown in FIGS. 8 and 9, burnishing of a surface inherently produces a Hertzian loading of the surface resulting in maximum compression beneath the surface of the work piece. The residual stress at the surface can be near zero or even tensile, and is a function of the direction of the burnishing operation. The surface residual stress is typically less compressive in the direction of burnishing (parallel) than in the transverse direction (perpendicular) due to the effect of displacement of material laterally during passage of the burnishing member. The presence of lower compression at the surface has been found to allow the initiation of fatigue cracks at the surface of the part. Although these cracks are arrested as they propagate deeper into the more highly compressive material, the presence of surface cracks and the stress intensity factor associated with them is highly undesirable. It has been found that the method of this invention comprising the steps of burnishing a part in combination with the secondary process identified herein above provides surface compression as well as deep compression resulting in a part having superior resistance to surface crack initiation and propagation. In another embodiment of the invention, the method of the present invention comprises the step, in conjunction with the first step of burnishing, of removing a layer of low compression by electropolishing, etching or other similar means that will not induce a state of stress or through mechanical means, such as low stress grinding, polishing, tumbling, or other such means, which will induce a state of shallow compressive stress.

Referring to FIG. 10, a preferred embodiment of the burnishing apparatus 100 for implementing the burnishing method of the subject invention is shown comprising a generally cylindrical socket 102 which conventionally mounts to a support 104 of any particular description typically used for supporting burnishing tools which is attached to a conventional machine tool fixture (not shown). In a preferred embodiment of the invention, the support 104 is coupled to the socket 102 and provides means for imparting a normal force F to a burnishing member 106 to effect the proper burnishing pressure sufficient to deform the surface 108 of the part 110.

The socket 102 includes a seat 112 adapted to the surface of the burnishing member 106 which is disposed within the seat 112, and an inner chamber 114. The size of the seat 112 is determined by the size and shape of the burnishing member 106 and is selected to provide a small clearance 116 between the seat 112 and the burnishing member 106. As shown, the support 104, in cooperation with the machine tool fixture, is adapted for controlling the movement of the socket 102 and includes means for forcing the socket 102 and the burnishing member 106 against the surface 108 of the part 110 being burnished. Without departing from the invention, it should now be apparent to those skilled in the art that various apparatus may be constructed to allow the socket to be moved to various positions or to allow the part being treated to rotate or pass in contact with the burnishing member in such a way that the selected region is burnished using the method of the present invention.

The socket 102 is further provided with a fluid passage 118 in flow communication with the seat 112 and extends from the seat 112 through the inner chamber 114 to a fitting (not shown) for connecting to a positive displacement pump 120 for providing a constant volumetric flow of fluid from a fluid supply 122 to the seat 112. The fluid supply 122 may be an external supply (not shown) or may be in the form of a sump 124, as shown, thereby forming a closed-loop fluid system. The positive displacement pump 120 is preferably coupled to a direct current (DC) electric motor 126 and a fast acting motor speed control 128. The motor speed control 128 functions to maintain a constant angular velocity of the motor 126 to sustain the constant volumetric fluid flow to the socket 102 regardless of any changes in fluid pressure. A pressure sensor 130, such as a pressure transducer, is connected to the fluid passage 118 for monitoring fluid pressure and is coupled to a control unit 132, such as a computer or a numerical controller, which is also coupled to either a position regulator 134, such as a spring, or a pressure regulator 136, such as a hydraulic or pneumatic system, that operate with the burnishing member 106 to provide the proper burnishing pressure being exerted against the surface 108 of the part 110.

To understand how the elements of this invention described are interrelated, the operation of the burnishing apparatus 100 will now be described. During operation, fluid, such as a lubricating fluid, is fed under pressure from the fluid supply 122 by use of the positive displacement pump 120 through the fluid passage 118 and into the inner chamber 114. The fluid in the inner chamber 114 is then fed under pressure around the burnishing member 106 through clearance 116 to force the burnishing member 106 outwardly. The lubricating fluid flows around the outer surface of the burnishing member 106 to permit the burnishing member 106 to float continuously upon a thin film of fluid. The socket 102 is then advanced towards the surface 108 of the part 110 by operation of the support and the machine tool fixture (not shown) until the forward most portion of the burnishing member 106 makes contact with the surface 108. By further adjusting the speed of the motor, a desired amount of lubrication fluid will flow around the burnishing member 106 and be transferred onto the surface 108 of the part 110 to provide the desired lubrication and cooling for the burnishing operation. During burnishing, the further most portion of the burnishing member 106 contacts the surface 108 of the part 110 causing the burnishing member 106 to move inwardly into the socket 102 thereby reducing the clearance 116 between the burnishing member 106 and the socket 102 thereby increasing the pressure of the fluid in the fluid passage 118. The increase in fluid pressure is detected by the pressure sensor 130 which is coupled to the control unit 132 that functions to adjust the force F being applied to the burnishing member 106 to maintain a constant or controlled variable burnishing pressure against the surface 108. It should now be apparent to those skilled in the art that the constant flow burnishing apparatus 100 of the present invention, unlike conventional constant pressure burnishing apparatus that follow the surface topography of the part, automatically increases the force F being applied to the burnishing member 106, and the corresponding pressure being exerted against the surface 108, on high points and decreases on low points along the surface 108. Accordingly, the pressure or the compressive force exerted on the surface 108 of the part 110 by the burnishing member 106 can be precisely regulated to provide optimum surface finish and uniform burnishing of the part.

In a preferred embodiment of the invention, the proper pressure or compressive force to be applied to the surface 108 of the part 110 during the burnishing operation is provided by using the position regulator 134 whereby the

force F being applied to the burnishing member 106 is a function of the position of the socket 102. As shown, the position regulator 134 includes a spring means 140, such as a coil spring, deflection members, or Belleville washers, having a known spring characteristic, which compresses or expands axially to apply a given normal force F to the burnishing member 106. Because the burnishing member 106 is coupled through the spring means 140, the force F being applied to the burnishing member 106 and the resulting pressure being exerted on the surface 108 of the part 110 can be accurately controlled by positioning (moving) the socket 102 using the conventional machine tool fixture (not shown). The control unit 132 operates with a feed back signal from the pressure sensor 130 to achieve closed loop control of the force F and the corresponding pressure being exerted on the surface by the burnishing member 106.

Preferably the machine tool fixture supporting the socket 102 is a "three-axis" machine that provides for linear motion along mutually orthogonal axis of a fixed coordinate system.

It should now be apparent to those skilled in the art that by using a programmable control unit 132 which is configured to continuously track the position of the burnishing member 106, the socket 102 can be accurately positioned and moved in a selected pattern. Further, in combination with passing the burnishing member is a selected pattern across the surface of the part, the pressure being exerted against the surface may be varied to obtain a region having the desired residual stress distribution and magnitude of compression.

In another preferred embodiment of the invention, the proper pressure or compressive force to be applied to the surface 108 of the part 110 during the burnishing operation is provided by use of the pressure regulator 136. As shown in FIG. 10, the pressure regulator 136 comprises a source of pressurized fluid 141 for providing pneumatic or hydraulic pressure against a piston 142, diaphragm or other similar means. The piston 142 is coupled to the burnishing member 106 in such a manner that movement of the piston 142 operates to increase or decrease the force F being applied to the burnishing member 106 thereby increasing or decreasing the corresponding pressure being exerted by the burnishing member 106 on the surface 108 of the part 110. In operation, for constant pressure burnishing, the machine tool fixture moves the socket 102 in a predetermined pattern along the surface 108 of the part 110. The control unit 132 functions with a feed back signal from the pressure sensor 130 to achieve closed loop control of the force F and the corresponding pressure being exerted on the surface 108 by the burnishing member 106. It should now be apparent to those skilled in the art that by using the control unit 132, the burnishing member 106 can be accurately moved in a selected pattern while exerting a predetermined pressure against the surface 108 of the part 110 to obtain a region having the desired residual stress distribution and magnitude of compression.

Conventional constant pressure burnishing apparatus require a containment means, such as end caps, for maintaining the burnishing member withing the apparatus. The containment means must be capable of withstanding high pressure and forces, including the time when the burnishing member is not in contact with the surface of the part. In the event that the containment means fails, the burnishing member could be propelled from the burnishing apparatus at high velocity. In contrast, the constant flow burnishing apparatus of the subject invention eliminates the need of a containment means that is capable of withstanding high pressure.

Referring to FIGS. 11, 12 and 13, the burnishing member 106 may be selected from various materials having a higher yield strength than the part 110 being burnished and having a relatively high elastic modules to allow maximal deformation of the part 110. In a preferred embodiment of the invention, the burnishing member 106 is formed from a high carbon steel or a sintered tungsten carbide containing a portion of a cobalt binder. The inner chamber 114 of the socket 102 is shown having a magnetic means 144, such as a permanent magnet or an electric magnet or the like, which produce magnetic flux 145 (FIG. 13) that functions to maintain the burnishing member 106 withing the seat 112. It has been found that forming the socket 102 from a ferromagnetic alloy, such as a martensitic stainless steel AISI 440C, the socket 102 functions as a pole piece thereby increasing the holding power of the magnet means 144. Because the bearing member 106 is supported by a low volume of fluid having a constant flow rate, the bearing member 106 will be retained within the socket 102 even while the fluid is flowing and the socket 102 is being repositioned or moved out of contact with the surface 108 of the part 110.

Referring to FIG. 14, a blade of the present invention is shown, for use in turbo machinery. The blade 146 includes a generally rectangular platform 148; an elongated airfoil 149 having a leading edge 150 and a trailing edge 152, the airfoil 149 being rigidly attached to and extending radially outwardly from the platform 148; and a root 154 rigidly connected to and extending radially inwardly from the platform 148 having a dovetail portion 155 for mounting to a rotor disk 156. As used herein, the term "outwardly" refers to the direction away from the center of rotation of the blade and rotor disk and the term "inwardly" refers to the direction towards the center of rotation of the blade and rotor disk. The rotor disk 156 includes a plurality of circumferentially spaced axially disposed slots 158 therein. The blade 146 is attached to the rotor disk 156 by inserting the root 154 into a slot 158. As shown, the root 154 and the slot 158 have complementing surfaces for securing the blade 146 to the rotor disk 156. During operation, the rotor disk 156 and the attached blades 146 are subjected to high centrifugal loads that produce high dynamic stresses that may cause high cycle fatigue along portions of the rotor disk 156 and each blade 146. Further, the leading edge 150 of the blade 146 is often subjected to damage by the impact of foreign objects in the fluid stream.

In a preferred embodiment of the invention, the blade 146 is treated by the method comprising a step or a combination of steps disclosed herein. In another preferred embodiment of the invention, the rotor disk 156 is treated by the method comprising a step or a combination of steps disclosed herein.

Another preferred embodiment of the invention, a part is selected from the group comprising automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, pump parts, and the like treated by the method comprising the step, or a combination of steps, of the present invention.

The method and apparatus for implementing the method of the subject invention utilizes a burnishing method that produces cold work and surface work hardening far less than either conventional shot peening, gravity peening, and conventional burnishing or deep rolling methods. The increase in residual compressive stress with minimal cold work developed by the subject invention penetrates to a greater depth than most conventional methods, such as shot peening and results in longer retention of compressive residual stress at elevated temperature, less rapid relaxation under cyclic

loading, and minimizes the alteration of the residual stress field during tensile or compressive overload, than conventional cold working and surface hardening processes. Accordingly, the method and apparatus for implementing the method of the subject invention provides a relatively inexpensive and effective means of providing a compression force on a workpiece to induce compressive residual stress in a well defined localized region of a simple or complex part surface configuration with a minimum of cold working and surface hardening. By minimizing the amount of cold working and surface hardening, the method of the subject invention produces longer retention of compressive residual stress at elevated temperature, less relaxation under cyclic loading, and minimizes the alteration of the residual stress field during tensile or compressive overload. Further, the method and the apparatus of the invention for inducing a layer of compressive residual stress along the surface of the part permits a variety of burnishing patterns to be designated to produce regions of residual stress that are appropriate for a specific engineering application. In addition, a part treated using the method of the invention have improved stress corrosion cracking resistance.

While the method and apparatus described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to the precise method and apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A method of reducing zones of high tensile stress in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

exerting a variable pressure against the surface of the selected region, the pressure being applied such that the magnitude of compression decreases in the direction towards the boundaries of the selected region to minimize the effects of any tensile stress zones near the boundaries.

2. The method of claim 1 wherein the pressure being exerted against the surface of the part is performed by a burnishing operation.

3. The method of claim 2 wherein the burnishing operation includes varying the burnishing density along the boundaries of the selected region.

4. The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

5. The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

6. The method of claim 1 further wherein the step of selecting the magnitude of compression includes the step of programming a control unit to automatically reduce the magnitude of compression in the direction towards the boundaries of the selected region.

7. The method of claim 1 wherein the step of exerting pressure against the surface of the selected region includes the step of programming a control unit to control the application of said pressure.

8. The method of claim 1 wherein the part is selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, and pump parts.

9. A method of reducing high tensile stress zones in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing, the magnitude of compression, and the pressure being applied against the surface are varied to reduce the high tensile stress zones along the boundaries of the selected region.

10. The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

11. The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

* * * * *

EXHIBIT 2

AMENDMENTS TO THE CLAIMS

<u>In the claims:</u>

1. (Amended) A method of reducing zones of high tensile stress in the surface of a part comprising the steps of:
   selecting a region of the part to be treated; and
   exerting a <u>controlled</u> variable pressure against the surface of the selected region, the pressure being applied such that the magnitude of compression decreases in the direction towards the boundaries of the selected region <u>in a controlled manner</u> to minimize the effects of any tensile stress zones near the boundaries.

2. (Original) The method of claim 1 wherein the pressure being exerted against the surface of the part is performed by a burnishing operation.

3. (Amended) The method of claim 2 wherein the burnishing operation includes varying the burnishing density <u>to modify the magnitude of compression</u> along the boundaries of-the selected region.

4. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

5. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

6. (Amended) The method of claim 1 [further] wherein the step of selecting the magnitude of compression includes the step of programming a control unit to automatically reduce the magnitude of compression in the direction towards the boundaries of the selected region <u>in a controlled manner</u>.

7. (Amended) The method of claim 1 wherein the step of exerting <u>controlled variable</u> pressure against the surface of the selected region includes the step of programming a control unit to control the application of said <u>controlled variable</u> pressure.

8. (Original) The method of claim 1 wherein the part is selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, and pump parts.

9. (Amended) A method of reducing high tensile stress zones in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of

burnishing, the magnitude of compression, and the pressure being applied against the surface are varied in a controlled manner to reduce the high tensile stress zones along the boundaries of the selected region.

10. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

11. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

EXHIBIT 3

INTERVIEW SUMMARY UNDER 37 CFR 1.560(b)

Application No.: 90/007,383

Patent No.: 6,622,570

Examiner: Minh Nguyen

Art Unit: 3992

Confirmation No.: 2869

All Participants:

Minh Nguyen, Examiner

Mark F. Smith (32,437), Attorney of Record

Brian A. Tent, (57,446), Attorney for Patent Owner

Paul S. Prevey, Inventor

Date of Interview: September 7, 2006

Type of Interview: Telephonic

Exhibits: No exhibits were shown

Rejections Discussed:

Claims 1-2 and 6-8, rejected under 35 U.S.C. 102(b) as being anticipated by the article "Application Description NR. AO-4088/1E, Deep Rolling", allegedly published on March 19, 1996 (hereinafter referred to as article AO-4088/1E).

Claims Discussed:

Claim 1 and the reasons for patentability/confirmation of Claims 3 and 9 - 11.

Prior Art Documents Discussed:

Article "Application Description NR. AO-4088/1E, Deep Rolling", allegedly published on March 19, 1996.

Substance of Interview:

The Interview was directed to three issues. The general nature of what was discussed is as follows:

1) Patentee has been unable to substantiate that article AO-4088/1E was actually publicly accessible on the publication date alleged by the third party requester. The Patentee requested guidance from the Examiner concerning the procedure for requesting verification that the reference was indeed published and available to the public on the date alleged by the third party requester. The Examiner was not familiar with the procedure and agreed to work with the Patentee to determine the proper procedure for requesting verification.

2) Claim 1 was discussed with respect to the terms "controlled variable pressure" and "controlled manner" as used in the Claim. Patentee proposed amending the claim to include the phrase "precisely and constantly regulated" with reference to the applied pressure. The Patent Examiner agreed, in substance, with the Patentee's arguments that continuous regulation and adjustment of the applied pressure distinguishes over the cited art. However, the patent Examiner indicated that the proposed language did not distinguish over the cited art. The Examiner suggested incorporating the following language to distinguish over the cited reference and place claim 1, and any claims depending from claim 1, in condition for allowance: <u>"monitoring the pressure at every position of the selected region</u>" with reference to the applied pressure.

3) The Examiner's Statement of Reasons for Patentability/Confirmation of Claims 3 and 9 - 11 were discussed. The Patentee has taken the position that the definition of the term "burnishing density" as used by the Examiner does not appear to be consistent with the definition of the term as use in the subject patent. The Examiner acknowledged that confusion over the definition of the term could exist and agreed to review his Statement and amend if necessary.

Respectfully submitted,

Mark F. Smith

September 8, 2006

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EXHIBIT 4

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/007,383	01/18/2005	6622570		2869

7590 09/22/2006

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EXAMINER

ART UNIT	PAPER NUMBER

DATE MAILED: 09/22/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
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9/22/2006

THIRD PARTY REQUESTER'S CORRESPONDENCE ADDRESS

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EX PARTE REEXAMINATION COMMUNICATION TRANSMITTAL FORM

REEXAMINATION CONTROL NO 90/007383

PATENT NO. 6,622,570

ART UNI 3992

Enclosed is a copy of the latest communication from the United States Patent and Trademark Office in the above identified ex parte reexamination proceeding (37 CFR 1.550(f)).

Where this copy is supplied after the reply by requester, 37 CFR 1.535, or the time for filing a replly has passed, no submission on behalf of the ex parte reexamination requester will be acknowledged or considered (37 CFR 1.550(g)).

Ex Parte Reexamination Interview Summary	**Control No.** 90/007,383	**Patent Under Reexamination** 6622570	
	Examiner Minh Nguyen	**Art Unit** 3992	

All participants (USPTO personnel, patent owner, patent owner's representative):

(1) *Minh Nguyen* (3) *Paul Prevey*

(2) *Mark Smith* (4) *Brian Tent*

Date of Interview: *07 September 2006*

Type: a)☒ Telephonic b)☐ Video Conference
c)☐ Personal (copy given to: 1)☐ patent owner 2)☐ patent owner's representative)

Exhibit shown or demonstration conducted: d)☐ Yes e)☒ No.
If Yes, brief description: _____

Agreement with respect to the claims f)☐ was reached. g)☐ was not reached. h)☒ N/A.
Any other agreement(s) are set forth below under "Description of the general nature of what was agreed to..."

Claim(s) discussed: *1*.

Identification of prior art discussed: *article AO-4088/1E*.

Description of the general nature of what was agreed to if an agreement was reached, or any other comments:
please see attachment.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims patentable, if available, must be attached. Also, where no copy of the amendments that would render the claims patentable is available, a summary thereof must be attached.)

A FORMAL WRITTEN RESPONSE TO THE LAST OFFICE ACTION MUST INCLUDE PATENT OWNER'S STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. (See MPEP § 2281). IF A RESPONSE TO THE LAST OFFICE ACTION HAS ALREADY BEEN FILED, THEN PATENT OWNER IS GIVEN **ONE MONTH** FROM THIS INTERVIEW DATE TO PROVIDE THE MANDATORY STATEMENT OF THE SUBSTANCE OF THE INTERVIEW (37 CFR 1.560(b)). THE REQUIREMENT FOR PATENT OWNER'S STATEMENT CAN NOT BE WAIVED. **EXTENSIONS OF TIME ARE GOVERNED BY 37 CFR 1.550(c).**

MARK J. REINHART
SPRE-AU 3992
CENTRAL REEXAMINATION UNIT

Examiner's signature, if required

cc: Requester (if third party requester)

1. The Patent Owner raises concerns about the publicly accessible of the reference AO-4088/1E and asks whether further information can be provided by the USPTO to show that the reference AO-4088/1E were indeed publicly accessible on March 19th, 1996 as indicated by the third party Requester.

2. The Patent Owner indicates that claim 1 requires that the applied pressure is precisely and constantly regulated by constantly monitoring the pressure at every position on the selected region. The monitoring process can be done, for example, by pressure sensor 130 as disclosed in the disclosure. Whereas the reference merely teaches the action of turning ON-OFF the hydraulic unit. The examiner suggests that the Patent Owner includes that language into the claim and file a request for reconsideration.

3. The Patent Owner clarifies the term "burnishing density" used in the claims and indicates that the term should be interpreted as described in column 8, lines 6-19 and Figs 5A-B of the US Patent No. 6,622,570 which is being reexamined.

MARK J. REINHART
SPRE-AU 3992
CENTRAL REEXAMINATION UNIT

EXHIBIT 5

AMENDMENTS TO THE CLAIMS

In the claims:

1. (Currently Amended) A method of reducing zones of high tensile stress in the surface of a part comprising the steps of:
selecting a region of the part to be treated; and
exerting a controlled variable pressure against the surface of the selected region, wherein the pressure being applied is precisely and constantly regulated by monitoring the pressure at every position of the selected region such that the magnitude of compression decreases in the direction towards the boundaries of the selected region in a controlled manner to minimize the effects of any tensile stress zones near the boundaries.

2. (Original) The method of claim 1 wherein the pressure being exerted against the surface of the part is performed by a burnishing operation.

3. (Previously Amended) The method of claim 2 wherein the burnishing operation includes varying the burnishing density to modify the magnitude of compression in the selected region.

4. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

5. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

6. (Previously Amended) The method of claim 1 wherein the step of selecting the magnitude of compression includes the step of programming a control unit to automatically reduce the magnitude of compression in the direction towards the boundaries of the selected region in a controlled manner.

7. (Previously Amended) The method of claim 1 wherein the step of exerting controlled variable pressure against the surface of the selected region includes the step of programming a control unit to control the application of said controlled variable pressure.

8. (Original) The method of claim 1 wherein the part is selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, and pump parts.

9. (Previously Amended) A method of reducing high tensile stress zones in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing, the magnitude of compression, and the pressure being applied against the surface are varied in a controlled manner to reduce the high tensile stress zones along the boundaries of the selected region.

10. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

11. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

REMARKS

Claims 1-11 remain in this reexamination application. Claims 1 - 2 and 4 - 8 stand rejected. Claim 1 has been amended as shown. Claims 3 and 9-11 are patentable and/or confirmed.

The amendment to Claim 1 is a result of a telephone Interview with the Examiner on September 7, 2006. An Interview Summary is attached hereto. During the Interview, the language of Claim 1 was discussed with regard to reference "Application Description NR. AO-4088/1E, Deep Rolling" that appears to have been published on March 19, 1996. During the Interview it was established that the Examiner does not believe that the term "controlled manner" as provided in independent Claim 1, does not render the metes and bounds of the claim clear. Accordingly, the Examiner suggested that Claim 1 be amended to place the Claim in better condition for allowance. In response to the Examiner's suggestion, Claim 1 has been herein amended to incorporate the Examiner's suggested claim language.

During the Interview, the Examiner's Statement of Reasons for Patentability/Confirmation of Claims 3 and 9 - 11 were also discussed. Based on the Interview, it appears that the Examiner's interpretation of the meaning of the term "burnishing density" is not consistent with the meaning expressed in the subject specification. Accordingly, it is the Patentee's understanding that the Examiner has agreed that the Claims should be reviewed in light of the meaning "burnishing density" provided by the subject specification.

Patentee submits the following remarks and hereby requests that this Amendment be admitted and entered and the patentability of Claims 1-2 and 4-8 confirmed.

I. Claim Rejections – 35 USC § 102

The Examiner's rejection of Claims 1-2 and 6-8 under 35 USC 102(b) as being anticipated by the article "Application Description NR. AO-4088/1E, Deep Rolling" (article AO-4088/1E, hereinafter) is respectfully traversed.

A reference anticipates a claimed invention when the reference teaches "every aspect of the claimed invention, either explicitly or impliedly". MPEP 706.02. When a cited reference does not explicitly or impliedly teach a feature, that feature must be inherently present in the cited reference in order to anticipate the claimed invention. MPEP 706.02. Patentee contends that article AO-4088/1E does not teach or otherwise contain all the limitations of Claims 1-2 and 6-8.

The Patentee submits that Claim 1, as amended, provides that the pressure being applied against the surface of the selected region and the magnitude of compression decreases in the direction towards the boundaries of the selected region in a controlled manner to minimize the effects of any tensile stress zones near the boundaries.

To accomplish this teaching, the subject patent discloses the following structure:

> A pressure sensor **130**, such as a pressure transducer, [] connected to the fluid passage **118** for <u>monitoring</u> fluid pressure and is coupled to a control unit **132**, such as a computer or a numerical controller, which is also coupled to either a position regulator **134**, such as a spring, or a pressure regulator **136**, such as a hydraulic or pneumatic system, that operate with the burnishing member **106** to provide the proper burnishing pressure being exerted against the surface **108** of the part **110**.

Prevey '570, col. 10, lines 11-20 and Fig. 10 (emphasis added). This combination of elements works in cooperation to deliver a precisely and constantly regulated ***controlled variable pressure*** in the following manner:

> during burnishing, the further most portion of the burnishing member **106** contacts the surface **108** of the part **110** causing the burnishing member

> **106** to move inwardly into the socket **102** thereby reducing the clearance **116** between the burnishing member **106** and the socket **102** thereby increasing the pressure of the fluid in the fluid passage **118**. The increase in fluid pressure is detected by the pressure sensor **130** which is coupled to the control unit **132** that functions to adjust the force **F** being applied to the burnishing member **106** to maintain a constant or ***controlled variable burnishing pressure*** against the surface of **108**.

Further, Prevey '570, col. 10, lines 41-52 and Fig. 10 (emphasis added). As a result, "the pressure of the compressive force exerted on the surface **108** of the part **110** by the burnishing member **106** can be **precisely regulated** to provide optimum surface finish and uniform burnishing of the part." Prevey '570, col. 10, lines 59-63.

Accordingly, the pressure is decreased towards the boundaries in a controlled manner. Further, as shown in the subject specification, the step of monitoring the pressure at every position of the selected region is inherent to the method of exerting a <u>controlled variable pressure</u> and further decreasing the magnitude of compression in the direction towards the boundaries of the selected region <u>in a controlled manner</u>.

In order to make the limitations of "exerting a controlled variable pressure" and "in a controlled manner" more clear, the Patentee has adopted the Examiner's suggestion and has amended Claim 1 accordingly. Claim 1 now provides:

> "...exerting a controlled variable pressure against the surface of the selected region, <u>wherein</u> the pressure being applied <u>is precisely and constantly regulated by monitoring the pressure at every position of the selected region</u> such that the magnitude of compression decreases in the direction towards the boundaries of the selected region in a controlled manner to minimize the effects of any tensile stress zones near the boundaries."

The Patentee respectfully submits that article AO-4088/1E does not teach, either expressly or impliedly, every aspect of Claim 1, as amended, of the subject patent. More specifically, article AO-4088/1E does not contain any teaching directed to decreasing the

magnitude of compression in the direction towards the boundaries of the selected region in a controlled manner, i.e. AO-4088/1E does not teach exerting a controlled variable pressure and/or applying pressure which is precisely and constantly regulated by monitoring the pressure at every position of the selected region.

The Examiner, citing page 4, second paragraph of article AO-4088/1E, takes the position that article AO-4088/1E discloses the application of variable pressure such that the magnitude of compression decreases in the direction towards the boundaries of the selected section. Patentee submits that article AO-4088/1E does not teach the application of a ***controlled variable pressure*** such that the decrease in the magnitude of compression is controlled in the direction towards the boundaries of the selected region. Further, the reference does not teach that the pressure is ***precisely and constantly regulated by monitoring the pressure at every position of the selected region***.

In addition, the "slow build up of the pressure" and "slow pressure drop" discussed in article AO-4088/1E is not accomplished in a controlled manner and the pressure is not precisely and constantly regulated and monitored, as in the subject patent but is, instead, a function of whether the "hydraulic unit" is turned on or off. This does not afford ***precisely and constantly regulated*** control over the rate at which pressure builds or decreases and there is no showing that the pressure is <u>monitored</u> at every position of the selected region. Instead, pressure builds at a fixed rate when the hydraulic unit is switched on and the pressure decreases at a fixed rate when the hydraulic unit is switched off. Article AO-4088/1E does not teach or disclose ***precisely and constantly regulating*** by monitoring the applied pressure and controlling the rate at which the applied pressure builds and decreases and adjusting the hydraulic pressure accordingly so

as to exert a ***controlled variable pressure*** and thereby adjust the magnitude of compression ***in a controlled manner*** as is taught in the subject patent.

In view of the foregoing whereby it has been shown that article AO-4088/1E does not teach every aspect of Claim 1 of the Prevey '570 patent, article AO-4088/1E does not anticipate Claim 1 of the Prevey '570 patent.

With regard to dependent Claims 2 and 6-8 collectively, any claim that depends from an allowed claim may also be allowed. *See Ex parte Ligh*, 159 USPQ 61, 62 (Bd. of Pat. App. & Inter. 1967). Therefore, provided that the Examiner has found persuasive Patentee's arguments in traverse of the rejection of Claim 1, Patentee respectfully submits that Claims 2 and 6-8, which depend directly from Claim 1, are in proper condition for allowance and requests favorable reconsideration of these Claims.

II. Claim Rejections – 35 USC § 103

Three criteria must be met in establishing a prima facie case of obviousness:

1. Some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine the reference teachings; and
2. A reasonable expectation of success; and
3. The prior art reference (or references when combined) must teach or suggest all the claim limitations.

MPEP § 2143. The Examiner has not established a prima facie case of obviousness with respect to Claims 4-5.

A. Claims 4 and 5

The rejection of Claims 4 and 5 under 35 U.S.C. 103(a) as being unpatentable over article AO-4088/1E in view of US Patent No. 5,826,453, issued to Prevey, III (hereinafter "Prevey '453"), is respectfully traversed.

The Examiner has rejected Claim 4 and Claim 5 as being unpatentable over article AO-4088/1E in view of Prevey '453. The Patentee restates the arguments made hereinabove with respect to Claim 1 from which both Claim 4 and Claim 5 depend. Further, the patentee respectfully submits that the combination of AO-4088/1E with Prevey '453 does not teach or suggest all the limitations of Patentee's Claim 4 or Claim 5. There is no suggestion or motivation in the cited references, and the Examiner has provided no such suggestion or motivation, to combine or modify either reference to read on the Claims of the subject invention nor is there any indication of a reasonable expectation of success. As such, the Examiner has failed to establish the prima facie case of obviousness with respect to Patentee's Claim 4 and Claim 5.

In view of the foregoing Amendments and Remarks, Patentee respectfully requests reconsideration of the Examiner's rejections and a favorable finding of patentability.

Respectfully submitted,

Mark F. Smith

September 8, 2006

Mark F. Smith (32,437)
Attorney of Record

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Reexam Cont. No. 90/007,383

CERTIFICATION OF SERVICE

I, Mark F. Smith, hereby certify that a copy of the attached response filed on September 8, 2006, has been sent on September 8, 2006, by First Class Mail, to Mr. Terry Jacobs, Ecoroll Corporation Tool Technology, 502 Technecenter Drive, Suite C, Milford, Ohio 45150.

Mark F Smith

September 8, 2006 Mark F. Smith

EXHIBIT 6

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Paul S. Prevey III
Reexam Cont. No.	:	90/007,383
Filed	:	01/18/2005
Patent No.	:	6,622,570
Title	:	METHOD FOR REDUCING TENSILE STRESS ZONES IN THE SURFAE OF A PART
Art Unit	:	3992
Examiner	:	Minh Nguyen
Docket No.	:	LRI-003RE

Mail Stop Ex Parte Reexam
ATTN: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, VA ~~22313-1450~~

PLEASE ENTER 9/26/06

AMENDMENT

Sir:

In response to the Final Office Action of August 11, 2006, please amend the above identified reexamination application as follows, and consider the attached remarks.

CERTIFICATE OF TRANSMISSION

I hereby certify that this correspondence is being transmitted to: Commissioner for Patents, P.O. Box 1450, Mail Stop Ex Parte Reexam, Central Reexamination Unit, Alexandria, VA 22313-1450, via Facsimile phone number 571-273-9900 on September 8, 2006.

September 8, 2006

Mark F. Smith

ok to enter

MARK J. REINHART
SPRE-AU 3992
CENTRAL REEXAMINATION UNIT

EXHIBIT 7

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/007,383	01/18/2005	6622570		2869

7590 10/03/2006

EXAMINER

Mark F. Smith
SMITH, BRANDENBURG & NOVAK LTD
905 Ohio - Pike
Cincinnati, OH 45245

ART UNIT	PAPER NUMBER

DATE MAILED: 10/03/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner for Patents
United States Patent and Trademark Office
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Alexandria, VA 22313-1450
www.uspto.gov

DO NOT USE IN PALM PRINTER

(THIRD PARTY REQUESTER'S CORRESPONDENCE ADDRESS)

Terry Jacobs

Ecoroll Corporation Tool Technology

502 Technecenter Dr., Suite C

Milford, OH 45150

EX PARTE REEXAMINATION COMMUNICATION TRANSMITTAL FORM

REEXAMINATION CONTROL NO. *90/007,383*.

PATENT NO. *6622570*.

ART UNIT *3992*.

Enclosed is a copy of the latest communication from the United States Patent and Trademark Office in the above identified *ex parte* reexamination proceeding (37 CFR 1.550(f)).

Where this copy is supplied after the reply by requester, 37 CFR 1.535, or the time for filing a reply has passed, no submission on behalf of the *ex parte* reexamination requester will be acknowledged or considered (37 CFR 1.550(g)).

Notice of Intent to Issue Ex Parte Reexamination Certificate	**Control No.** 90/007,383	**Patent Under Reexamination** 6622570	
	Examiner Minh Nguyen	**Art Unit** 3992	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ Prosecution on the merits is (or remains) closed in this *ex parte* reexamination proceeding. This proceeding is subject to reopening at the initiative of the Office or upon petition. *Cf.* 37 CFR 1.313(a). A Certificate will be issued in view of
   (a) ☒ Patent owner's communication(s) filed: *08 September 2006*.
   (b) ☐ Patent owner's late response filed: _____.
   (c) ☐ Patent owner's failure to file an appropriate response to the Office action mailed: _____.
   (d) ☐ Patent owner's failure to timely file an Appeal Brief (37 CFR 41.31).
   (e) ☐ Other: _____.

   Status of *Ex Parte* Reexamination:
   (f) Change in the Specification: ☐ Yes ☒ No
   (g) Change in the Drawing(s): ☐ Yes ☒ No
   (h) Status of the Claim(s):
   (1) Patent claim(s) confirmed: _____.
   (2) Patent claim(s) amended (including dependent on amended claim(s)): *1-11*
   (3) Patent claim(s) cancelled: _____.
   (4) Newly presented claim(s) patentable: _____.
   (5) Newly presented cancelled claims: _____.

2. ☒ Note the attached statement of reasons for patentability and/or confirmation. Any comments considered necessary by patent owner regarding reasons for patentability and/or confirmation must be submitted promptly to avoid processing delays. Such submission(s) should be labeled: "Comments On Statement of Reasons for Patentability and/or Confirmation."

3. ☐ Note attached NOTICE OF REFERENCES CITED (PTO-892).

4. ☐ Note attached LIST OF REFERENCES CITED (PTO/SB/08).

5. ☐ The drawing correction request filed on _____ is: ☐ approved ☐ disapproved.

6. ☐ Acknowledgment is made of the priority claim under 35 U.S.C. § 119(a)-(d) or (f).
   a)☐ All b)☐ Some* c)☐ None of the certified copies have
   ☐ been received.
   ☐ not been received.
   ☐ been filed in Application No. _____.
   ☐ been filed in reexamination Control No. _____.
   ☐ been received by the International Bureau in PCT Application No. _____.

   * Certified copies not received: _____.

7. ☐ Note attached Examiner's Amendment.

8. ☐ Note attached Interview Summary (PTO-474).

9. ☐ Other: _____.

Minh Nguyen
Primary Examiner
Art Unit: 3992

cc: Requester (if third party requester)

UNITED STATES DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

REEXAMINATION

REASONS FOR PATENTABILITY / CONFIRMATION

Reexamination Control No. *90/007,383* Attachment to Paper No. *20060926*.

Art Unit *3992*.

Please see attached papers.

(Examiner's Signature)

PTOL-476 (Rev. 03-98)

STATEMENT OF REASONS FOR PATENTABILITY AND/OR CONFIRMATION

1. The following is an examiner's statement of reasons for patentability and/or confirmation of the claims found patentable in this reexamination proceeding:

Claims 1-11 are allowed and/or confirmed.

Claim 1 is patentable because the prior art of record fails to disclose or suggest the step of exerting a controlled variable pressure against the surface of the selected region wherein the variable pressure is constantly monitored and regulated at every position of the selected region. The inclusion of the recited step defines patentability over the prior art of record because it defines a distinguished action for reducing zones of high tensile stress in a surface of a part which is not taught by the prior art of record, alone or in combination. The closest references, article AO-4088/1 E and Operating Instructions No. 080592E/3, teach the step of exerting to apply a controlled variable pressure against the surface of the selected region. However, it does not teach the variable pressure being constantly monitored and regulated at every position of the selected region as recited in the claim. These articles expressly teach this step by turning OFF the hydraulic unit to create a variable pressure when the unit is moving towards the boundaries; however, when the unit is OFF, the pressure can not be regulated at every position of the selected region. Other references of record only describe the tools used for burnishing but fail to teach this specific step for reducing zones of high tensile stress in a surface of a part.

Claims 2-8 are dependent of claim 1, and therefore, they are allowed for the same reason noted in claim 1.

Claim 9 is patentable because the prior art of record fails to disclose or suggest the step of varying both the burnishing density and the magnitude of compression in a controlled manner (the meaning of the term “burnishing density” is described in figure 5 and col 8:6-19). The inclusion of this step defines patentability over the prior art of record because it defines a distinguished action for reducing zones of high tensile stress in a surface of a part which is not taught by the prior art of record, alone or in combination. The closest references, article AO-4088/1 E and Operating Instructions No. 080592E/3, do not teach the step of increasing and decreasing spacing of the pressure between each pass in addition to exerting a variable pressure on the surface of the part as recited in the claim. Other references of record only describe the tools used for burnishing but fail to teach this specific step for reducing zones of high tensile stress in a surface of a part.

Claims 10-11 are dependent of claim 9, and therefore, they are confirmed for the same reason noted in claim 9.

Any comments considered necessary by PATENT OWNER regarding the above statement must be submitted promptly to avoid processing delays. Such submission by the patent owner should be labeled: "Comments on Statement of Reasons for Patentability and/or Confirmation" and will be placed in the reexamination file.

2. **All** correspondence relating to this *ex parte* reexamination proceeding should be directed as follows:

By **U.S. Postal Service Mail** to:

Mail Stop *Ex Parte* Reexam
ATTN: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By FAX to:

571-273-9900
Central Reexamination Unit

By hand to:

Customer Service Window
Randolph Building
401 Dulany St.
Alexandria, VA 22314

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Minh Nguyen whose telephone number is 571-272-1748. The examiner can normally be reached on Monday, Tuesday, Thursday, Friday 7:00-5:30. If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Mark Reinhart, can be reached on 571-272-1611.

4. Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Conferee # 1

Conferee # 2

Minh Nguyen
Primary Examiner
Art Unit 3992

MARK J. REINHART
SPRE-AU 3992
CENTRAL REEXAMINATION UNIT

EXHIBIT 8

US006622570C1

(12) **EX PARTE REEXAMINATION CERTIFICATE** (6442nd)

United States Patent (10) **Number: US 6,622,570 C1**

Prevey, III (45) **Certificate Issued: Sep. 16, 2008**

(54) **METHOD FOR REDUCING TENSILE STRESS ZONES IN THE SURFACE OF A PART**

(75) Inventor: **Paul S. Prevey, III**, Cincinnati, OH (US)

(73) Assignee: **Surface Technology Holdings, Ltd.**, Cincinnati, OH (US)

Reexamination Request:
No. 90/007,383, Jan. 18, 2005

Reexamination Certificate for:

Patent No.:	**6,622,570**
Issued:	**Sep. 23, 2003**
Appl. No.:	**09/516,327**
Filed:	**Mar. 1, 2000**

(51) **Int. Cl.**
G01N 3/08 (2006.01)

(52) **U.S. Cl.** **73/826**; 72/75
(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,947,668 A		8/1990	Ostertag	
5,826,453 A	*	10/1998	Prevey, III	72/75
6,622,570 B1		9/2003	Prevey, III	

OTHER PUBLICATIONS

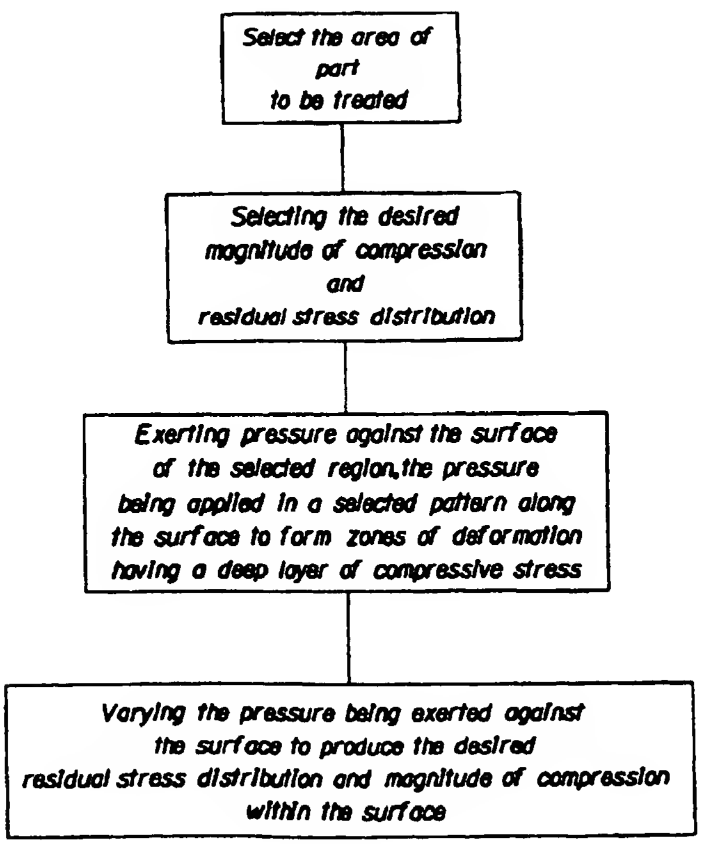
"Practical Metallurgy", 1940, pp. 121–123, George Sachs and Kent R. Van Horn, ASM.
"Application Description NR. AO-7088/IE Deep Rolling", Mar. 19, 1996, Ecoroll AG Werkzeugtechnik, Celle, Germany.
"Operating Instructions, No. 080592E/3, Hydrostatic Roller Burnishing Tool HG4–HG6–, HG13–9", Oct. 10, 1996, Ecoroll AG Werkzeugtechnik, Celle, Germany.
"Tools for Roller Burnishing, Deep Rolling, Forming", pp. 2.9–2.12 and 5.1, Apr. 1996, Ecoroll AG Werkzeugtechnik, Celle, Germany.

* cited by examiner

Primary Examiner—Minh Nguyen

(57) **ABSTRACT**

The present invention is a novel method for reducing tensile zones in the surface of a part comprising the steps of selecting a region of the part to be treated and programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing and the magnitude of compression are varied to reduce the high tensile stress along the boundaries of the selected region. In a preferred embodiment of the invention the burnishing operation induces a deep layer of compression within the surface having associated cold working of lens than about 5.0 percent.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1**, **3**, **6**, **7** and **9** are determined to be patentable as amended.

Claims **2**, **4**, **5**, **8** and **10–11**, dependent on an amended claim, are determined to be patentable.

1. A method of reducing zones of high tensile stress in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

exerting a *controlled* variable pressure against the surface of the selected region, the pressure being applied such that the magnitude of compression decreases in the direction towards the boundaries of the selected region *in a controlled manner* to minimize the effects of any tensile stress zones near the boundaries.

3. The method of claim **2** wherein the burnishing operation includes varying the burnishing density *to modify the magnitude of compression* along the boundaries of the selected region.

6. The method of claim **1** [further] wherein the step of selecting the magnitude of compression includes the step of programming a control unit to automatically reduce the magnitude of compression in the direction towards the boundaries of the selected region *in a controlled manner*.

7. The method of claim **1** wherein the step of exerting *controlled variable* pressure against the surface of the selected region includes the step of programming a control unit to control the application of said *controlled variable* pressure.

9. A method of reducing high tensile stress zones in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing, the magnitude of compression, and the pressure being applied against the surface are varied *in a controlled manner* to reduce the high tensile stress zones along the boundaries of the selected region.

* * * * *

EXHIBIT 9

Claims as Ordered Entered Sept. 26, 2006

1. (Currently amended) A method of reducing zones of high tensile stress in the surface of a part comprising the steps of:

selecting a region of the part to be treated; and

exerting a controlled variable pressure against the surface of the selected region, wherein the pressure being applied is precisely and constantly regulated by monitoring the pressure at every position of the selected region such that the magnitude of compression decreases in the direction towards the boundaries of the selected region in a controlled manner to minimize the effects of any tensile stress zones near the boundaries.

2. (Original) The method of claim 1 wherein the pressure being exerted against the surface of the part is performed by a burnishing operation.

3. (Previously Amended) The method of claim 2 wherein the burnishing operation includes varying the burnishing density to modify the magnitude of compression in the selected region.

4. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

5. (Original) The method of claim 1 wherein said pressure being exerted on the surface of the part induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.

6. (Previously Amended) The method of claim I wherein the step of selecting the magnitude of compression includes the step of programming a control unit to automatically reduce the magnitude of compression in the direction towards the boundaries of the selected region in a controlled manner.

7. (Previously Amended) The method of claim 1 wherein the step of exerting controlled variable pressure against the surface of the selected region includes the step of programming a control unit to control the application of said controlled variable pressure.

8. (Original) The method of claim 1 wherein the part is selected from the group consisting of automotive parts, aircraft parts, marine parts, engine parts, motor parts, machine parts, drilling parts, construction parts, and pump parts.

9. (Previously Amended) A method of reducing high tensile stress zones in the surface of a part comprising the steps of;

selecting a region of the part to be treated; and

programming a control unit of a burnishing apparatus to perform a burnishing operation, the burnishing operation being performed such that the density of burnishing, the magnitude of compression, and the pressure being applied against the surface are varied in a controlled manner to reduce the high tensile stress zones along the boundaries of the selected region.

10. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 5.0 percent.

11. (Original) The method of claim 9 wherein said burnishing operation induces a deep layer of compression within the surface having associated cold working of less than about 3.5 percent.